EPRICON: Agentless Flue Gas Conditioning For Electrostatic Precipitators

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INTRODUCTION

Achieving efficient particulate control in coal burning electric utility plants is becoming an increasingly difficult proposition, given the variety of regulatory, technical, operating and environmental pressures that exist in the U.S.

For most powerplants, particulate control is achieved by an electrostatic precipitator (ESP). Under optimal conditions, modern ESPs are capable of achieving particulate removal efficiencies of 99.7% and higher... well within the regulatory levels prescribed by the Clean Air Act. Unfortunately, optimal conditions are not always present. ESPs are sensitive to flue gas conditions, and those conditions may change dramatically after a fuel switch or the installation of some types of emissions control technology upstream of the ESP.

Gas conditioning has been shown to be an effective means of returning flue gas to the "optimal" conditions required for efficient ESP operation following a fuel switch to a low, or at least, lower sulfur coal. Borrowing technology common in conventional soap-making plants around the turn of the century, sulfur-burning SO_3 gas conditioning has been the solution to may difficult fuels in electrostatic precipitators. Although it has contributed most to improved ESP performance after a fuel switch, conventional gas conditioning has significant drawbacks, including the need for maintaining a little chemical plant, and otherwise storing or handling toxic materials.

In an effort to develop an alternative to conventional SO_3 gas conditioning, the Electric Power Research Institute (EPRI) initiated a research and development project that has produced an alternative and modern technology for flue gas conditioning, now called EPRICON, and licensed it to Research-Cottrell.

FLUE GAS CONDITIONING

Changing Flue Gas Conditions

The majority of ESPs now operated by U.S. electric utilities are more than 20 years old, and were designed to operate primarily on high sulfur fuels. When designed, these devices were capable of meeting opacity standards of 20 per cent and emissions levels in the range of 0.1 lb/MMBtu. Those earlier emissions control standards have been replaced by a host of subsequent regulations, most recently the Clean Air Act Amendments of 1990, many of which directly or indirectly affect particulate collection.

Switching from high sulfur to a lower sulfur coal is currently the favored means of attaining compliance under Title IV of the CAAA, which regulates acid gas emissions. Different coals have different chemical and physical characteristics, however, and can be expected to change flue gas conditions and particulate properties substantially. Some low sulfur coals have high ash contents, for example, and will increase particulate loading, which may strain the ash handling system. For coals with a very low sulfur content, typically one per cent or below, the resulting flyash exhibits high electrical resistivity, which may significantly reduce ESP performance.

Addressing High Resistivity

A small fraction of the SO_2 produced by the combustion of coal is converted to SO_3 (typically less than 2%). When temperature and humidity conditions are favorable, the SO_3 thus generated is absorbed on the surface of the flyash particles and is sufficient to reduce ash electrical resistivity.

Under acceptable resistivity levels and other good operating conditions, ESPs can achieve collection efficiency over 99.9%. High particle resistivity (typically above 5E10 ohm.cm) will decrease the ESP's overall collection efficiency, however, because dust begins to limit current flow and sparking voltage in the ESP. As an alternative to enlarging the ESP, gas conditioning can restore the required resistivity conditions to ideal performance levels.

Early applications of gas-conditioning used liquid SO_3 which was vaporized and diluted with dry air, or concentrated sulfuric acid, which was vaporized with hot air. A second generation of gas-conditioning technology using SO_2 as feed material was developed. More recently, burning molten elemental sulfur to produce SO_2 prior to the catalyst bed was proven, and this technology emerged in the 1970's as the dominant choice.

The EPRICON Process

The EPRICON process provides required gas conditioning without the need for external agents, such as liquid SO_2 or vaporized molten sulfur. In addition, it eliminates the need to filter the gas of particulates prior to its entry into the gas-conditioning chamber, and eliminates the need for an additional fan to move the conditioned gas into the electrostatic precipitator.

The process (Figure 1) operates by withdrawing a small fraction of the flue gas from a location in the boiler where the operating temperature is in the range of 800°F to 900°F. This fraction of flue gas, or slipstream, is then passed over a catalyst heated by the gas, where between 30-70 percent of the SO_2 in the flue gas is converted to SO_3. The slipstream, now SO_3-rich, is re-injected after the air preheater but ahead of the ESP to provide the required SO_3 for the reduction of resistivity.

The feasibility of the technology is dependent on case-by-case conditions. If, for example, 5ppm of SO_3 can treat the ash adequately and the flue gas contains 500 ppm, from 1 to 2 percent of the gas must be treated. Conversely, if 15 ppm of SO_3 is needed, a little over 3 percent of the gas containing 500 ppm of SO_2 would have to be treated. Three percent is considered to be the upper limit of a range for continuous operation that has been identified as economically and technically desirable, although operation above this range to deal with difficult but temporary coal supplies is feasible.

PILOT PLANT

A pilot program on a pulverized coal-fired boiler was conducted by EPRI to determine the operability of the catalyst in a slip-stream flue gas system over a period of time. The pilot system was constructed at Alabama Power Company's plant Miller and identified a number of design parameters for the EPRICON process. This pilot is still in operation.

FULL SCALE DEMONSTRATION

In the spring of 1994, Research-Cottrell designed and installed a full-scale turnkey EPRICON system on a 250MW public utility boiler in the Northeastern U.S. This boiler is about 25 years old, and was originally designed to fire a high sulfur coal. The new compliance coal is to cover a wide variety of sources all of which will contain much lower sulfur than the original design. The boiler is equipped with its original precipitator, which cannot meet emissions regulations while the boiler is firing compliance sulfur coal.

This full scale demonstration system (Figure 2) incorporated the fundamental premises of the EPRICON technology, such as avoidance of pre-cleaning the gas (the catalyst operates in "dirty" raw flue gas) and the absence of an air mover to push the slipstream through the catalyst chamber (gas flow is induced through the catalyst by the differential pressure across the air preheater). The full scale system also borrowed some of the design parameters of the pilot program, mainly the catalyst itself and its arrangement, but after that, the differences from the pilot were many.

Inlet Duct

The boiler is physically split in the convective section, which provided the convenient design choice to provide two parallel catalyst chambers, each with its own gas take-off. The boiler gas remains split all the way through the precipitators, which is ideal for side-by-side diagnostic and characterization tests. Also, there was no need to mix gas from two different temperature sources.

The twin inlet ducts are fabricated from 1/4" ASTM-A242 plate and insulated with 5" of mineral wool covered with a flat aluminum lagging. The ducts are simply supported at the boiler casing penetration and the top of the catalyst vessels. An expansion joint, a guillotine isolation damper, and motorized flow control damper are installed right at the boiler off-take.

Catalyst Chamber

Although there is a variety of catalyst formulations and substrates that can perform the necessary conversion, it was decided to stay with the same catalyst that was selected for the pilot. (Figure 3) The chamber is a rectangular cross-section 6'-6 x 10'-4, fabricated from 1/4" A242 plate and has the catalyst blocks arranged in six (6) layers (two (2) layers have purposely been left empty for future catalyst addition, if necessary). The catalyst is supported in the chambers by means of fabricated tee sections. The gas flow through the chamber is vertically downward.

A generous gap was left between catalyst layers for fitting with "puff" blowers to knock of ash deposits that can form on the flat tops of the catalyst blocks, but acoustic devices were also installed as a alternative to air blowing.

Outlet Duct And Distribution System

This outlet duct is fitted with a guillotine shut-off damper provided to isolate the chamber for maintenance. Penetration of converted flue gas into the main gas duct is by means of a unique "expansion box" from which the distribution header is hung. The header answered one of the questions from the pilot study: simple injection pipes and full height air foils have proven excellent performance in terms of treated gas injection and distribution upstream of a precipitator that is very close coupled to the air preheater.

System Control

Modulation of the system is simple. A flow transmitter in the inlet duct modulates a double lovered flow control damper in the inlet duct directly down stream of the inlet isolation guillotine.

PERFORMANCE

Characterization tests were run in June and July 1994, using a variety of extraction and instrumented test procedures.

Flow rates were established using EPA approved methods with a pilot tube and thermocouple. Good agreement was achieved on the North (designated side 11) chamber between the measured flow rate and the flow rate indicated by the installed electronic flow meter. Flow rates were measured at full boiler load and at a reduced boiler load. At full load, gas volumetric flow rate ranged from 23,500 to 28,200 ACFM at approximately 850°F per side. Lower boiler load tests were run between 13,400 and 15,300 ACFM per side.

SO_3 Conversion

SO_3 was measured at the inlet and outlet of the EPRICON chamber during 16 characterization tests using both an analyzer installed on the boiler and by standard wet chemical procedure. Again, agreement between these methods was good, so eventually, most reliance was placed on the instrument reading which, besides being faster, tends to be more accurate. SO_3 measurements by analyzer are not possible, so the Goksoyr-Ross controlled condensation method was used.

SO_3 conversion can be approximated by the difference in SO_2 concentration at the inlet and outlet of the EPRICON chamber, and by direct measurement in SO_3 at the inlet and outlet, the difference being the apparent conversion from SO_2 to SO_3 by the action of the catalyst.

Direct SO_3 measurement indicated a conversion from about 10 ppm at the inlet to about 200 ppm at the outlet, for an average conversion of over 70% at full load expressed in standard units. (Figure 4) At low load, conversion increased, as expected, to about 85%. Compared to SO_2 measurements, the SO_3 levels at the outlet of the chamber appear to be understated. However, the Goksoyr-Ross method is a non-isokintetic technique which would tend to under-collect fly ash at the EPRICON outlet. If any SO_3 were to become attached to flyash particles, perhaps by adsorption above the condensation temperature, this fraction of the converted SO_2 could easily be missed by the test method.

Conditions At The Precipitator Inlet

SO_3 concentrations at the ESP inlet ranged between 12 and 23 ppm at high and low boiler loads, respectively. SO_3 and temperature uniformity were of great interest in the design stage, so gas sampling at several locations in a grid across the ESP face was done to measure both SO_3 and gas temperature.

The results showed acceptable uniformity for both parameters, and prove the adequacy of the injection apparatus for this technology. Temperatures were also measured with EPRICON dampered off. Average flue gas temperature rise across the face of the ESP was uniformly above 10°F, a little lower than expected, which is most likely attributable to the somewhat lower than expected gas outlet temperature from the chambers. SO_3 concentration again is probably slightly understated due to the non-isokinetic nature of the direct measurement procedure.

Flyash Resistivity And Precipitator Current Density

Fly ash resistivity was not measured directly during these first characterization tests, but ESP power levels were recorded with and without EPRICON valved in. Power levels were, monitored with one EPRICON chamber on line and the other chamber cut off with its outlet isolation damper. The on-line chamber was then shut off and the other chamber was brought on line.

In each case, the change in ESP power was significant and rapid, showing a strong correlation between EPRICON chamber SO_2 content and ESP corona power. (Figure 5) The fact that each EPRICON chamber serves a separate precipitator reinforces this conclusion. Total ESP power was increased about 200% on Side 11 28 kw to 68 kw and a little less on Side 12 (35 kw to 65 kw). Overall ESP was increased from 0.25/Watts/Ft2 to 0.53 Watts/Ft2.

Second Full Scale Unit

In October, 1994, work began on a second EPRICON system on a near-identical 250MW boiler at the same plant site. Since a complete battery of characterization and performance tests were not completed prior to the decision to install this second system, the catalyst chambers are virtually identical except that the second unit has a simpler access system. This unit was completed in December, 1994.

THE BOTTOM LINE

Compared to conventional gas conditioning, the EPRICON gas conditioning system minimizes the need for external chemicals or apparatus to achieve a reduction of resistivity. The system is applicable to power stations with high resistivity ash, often produced by the use of low-sulfur coals, that can be treated adequately with SO_3. That reduction of electrical resistivity will enhance the performance of the ESP particulate-collection device.

Capital Cost

Based on these two, 250 MW installations, the EPRICON technology is expected to cost under $4.50/kw on a completely installed turnkey basis. These two boilers are big enough to scale well to most other utility sizes except perhaps units over 600 MW or so. Between 100 and 600 MW, the use of dual chambers should be a preferred choice when separate or unitized precipitators are installed, and this is typically the case. Installation labor and auxiliaries such as dampers, expansion joints, and access systems comprise over 50% of the total system cost.

Operating Costs

The operating costs of EPRICON are noted in two areas: thermal penalty due to the 3 percent of flue gas unavailable for heat exchange through the air preheater, and maintenance of the catalyst bed. Thermal penalties are estimated to be insignificant for slipstreams of 3 percent or below however, this assumption will be vigorously tested in full scale tests. Catalyst rejuvenation costs are anticipated every two years to restore SO_2 conversion efficiency at a minimum of 50 percent. This translates to less than 7 cents per kw per year.

A second maintenance cost is incurred for catalyst replacement as a result of breakage. Catalyst replacement costs are estimated at approximately $1,000 annually.

Present Status

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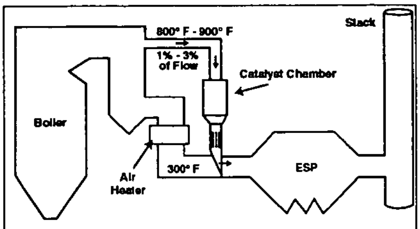

Figure 1. EPRICON Process

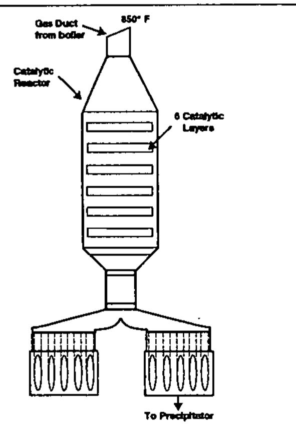

Figure 2. Full Scale System
(one of two sides)

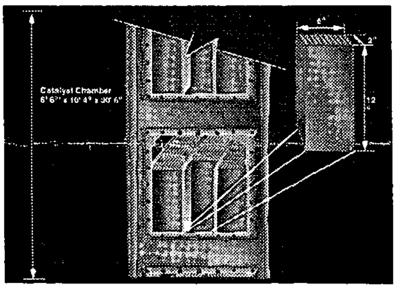

Figure 3. Catalyst

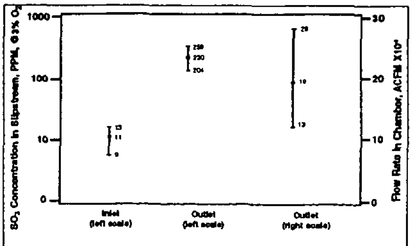

Figure 4. Apparent SO_3 Enrichment

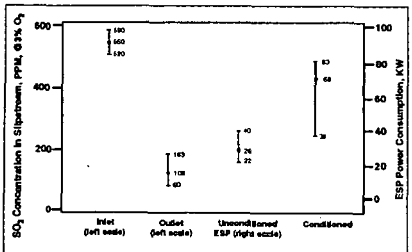

Figure 5. Precipitator Power Enhencement